Vehicle-Wildlife Collisions

by

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Executive Summary

Vehicle-wildlife collisions are becoming an increasing problem in Canada and the United States. The number of accidents which occur is increasing annually. The importance of coming up with successful mitigation methods is becoming more evident. There are several methods currently used to mitigate this problem but the level of success for the various methods vary.

Highway signs appear to produce only minimal results in preventing ungulate collisions. The effectiveness of roadside deer reflectors is inconclusive. A combination of fencing and underpasses is very effective but is quite an expensive endeavor.

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1.0 Introduction

Animal-vehicle collisions on highways are a significant problems for the users of the highway networks. In New Brunswick, these accidents represent approximately five percent of the total reportable motor vehicle accidents. The problem of vehicle-wildlife collisions arise when highways are constructed through habitats where wildlife are concentrated or when highways intersect with wildlife migration routes.

Vehicle-wildlife collisions result in the loss of human life, loss of wildlife, and property damage. These accidents account for millions of dollars in property damage and medical expenses. Due to the dangerous situation that exists, methods to rectify the problem are becoming more important.

1.1 Study Objectives

Current design considerations and mitigation methods used by highway authorities are highlighted in this paper. These techniques are discussed relative to their effectiveness and their financial feasibility. Certain mitigation methods are analyzed on a cost- benefit basis and the results are presented in this paper.

2.0 Deer and Moose Accidents

The collisions between vehicles and deer or moose need to be quantified to ascertain whether New Brunswick has a severe problem with these collisions.

2.1 New Brunswick Experience

In New Brunswick, Deer and Moose collisions account for approximately 5.5 percent of the total yearly accidents. These accidents total approximately 1000 collisions per year. Table 1 contains the statistics for Deer and Moose collisions in New Brunswick for the years 1985 to 1994 inclusively.

Since 1992, the New Brunswick Department of Transportation has separated the statistics of Deer collisions from those of Moose collisions. From Table 1 it can be observed that the severity of Deer collisions normally consist of five percent of injury producing accidents and ninety-five percent property damage accidents. Although there was a fatal accident involving a Deer in 1994, this collision proved to be an anomaly. The fatal collisions for the years 1988 to 1991 were reviewed and it was concluded that all of these fatal collisions involved Moose and none involved Deer.

Similarly, the severity breakdown of Moose collisions consists

of seventy-four percent property damage accidents, twenty-five percent injury accidents, and one percent fatal accidents. The data contained in Table 1 also seems to indicate that approximately sixty percent of Deer collisions occur during the night compared to eighty percent of Moose collisions which occur during dark conditions. These data confirm the suspected phenomena that the majority of ungulate collisions occur during reduced visibility conditions.

2.2 Other Jurisdictions

Table 2 shows the total number of animal collisions for the ten Canadian provinces and the two Territories for the year 1992. Of the ten provinces, New Brunswick has the fourth lowest total number of animal collisions with a total of 1107 collisions. According to Table 2, Manitoba experienced 1677 animal collisions in 1992.

It is interesting to note that the Driver, Vehicle and Traffic Accident Statistics Report 1991 published by the Manitoba Highways and Transportation Department shows that 3.9 percent of vehicles in collisions were involved with animals. This number compares very closely with New Brunswick where 4.1 percent of vehicle instances in 1991 involved collisions with animals.

Saskatchewan experiences considerably more animal collisions

TABLE 1

Deer / Moose Collisions 1985 - 1991

Year	Property Damage	Injury	Fatal	Total	% Night	% Total
1985	730	85	2	817	62	4.9
1986	845	96	0	941	57	5.1
1987	943	94	0	1,037	65	5.1
1988	1,002	103	1	1,106	61	5.3
1989	1,043	109	0	1,152	60	5.3
1990	1,010	106	4	1,120	60	5.4
1991	1,023	101	2	1,126	55	5.6

Deer / Moose Collisions 1992

Year	Property Damage	Injury	Fatal	Total	% Night	% Total
Deer	801	45	0	846	62	4.6
Moose	174	52	2	228	81	1.2
Total	975	97	2	1,074		5.8

Deer / Moose Collisions 1993

Year	Property Damage	Injury	Fatal	Total	% Night	% Total
Deer	612	36	0	648	58	4.1
Moose	155	47	2	204	80	1.3
Total	767	83	2	852		5.4

Deer / Moose Collisions 1994

Year	Property Damage	Injury	Fatal	Total	% Night	% Total
Deer	659	40	1	700		
Moose	148	61	3	212		
Total	807	101	4	912		

Note: Approximately 5% of Deer Collisions are Injury
Approximately 10% of Deer / Moose Collisions are Injury

TABLE 2

1992 Traffic Collision Data
Vehicle Events 1,2,3 By Collision Severity

Province	Vehicle Events 1,2,3	Fatal	Non-Fatal Injury	Property Damage	Grand Total
Newfoundland	Hit Animal	2	59	311	372
P.E.I.	Hit Animal	0	3	20	23
Nova Scotia	Hit Animal	0	99	771	870
New Brunswick	Hit Animal	2	96	1,009	1,107
Quebec	Hit Animal	5	153	3,022	3,180
Ontario	Hit Animal	6	458	6,439	6,903
Manitoba	Hit Animal	0	90	1,587	1,677
Saskatchewan	Hit Animal	0	133	5,572	5,705
British Columbia	Hit Animal	3	333	2,898	3,234
Yukon	Hit Animal	0	3	20	23
Northwest Territories	Hit Animal	0	2	6	8
Grand Total		18	1,429	21,655	23,102

Source Transport Canada - Road Safety -TRAID(V04)

than New Brunswick with 5705 reported in 1992. According to the 1991 & 1992 Saskatchewan Traffic Accident Facts report published by the Saskatchewan Highways and Transportation Department, wildlife collisions in that province constitute 48 percent of all accidents in rural areas. These numbers are reported to consists mostly of Deer collisions. Comparatively, New Brunswick Deer collisions consists only of 16 percent of rural collisions.

The Roadkill magazine reported animal collisions occurring in forty-three American States for the year 1992. Twenty-nine out of the forty-three States reported to have animal collisions in excess of New Brunswick's experience for the year 1992. The top six States had in excess of Sixteen thousand reported collisions with the top two experiencing over forty thousand animal collisions.

In summary, the number of animal collisions in New Brunswick seems low in comparison to the majority of other Canadian Provinces and American States. However, the extent of this problem is only as severe as perceived by the public and the New Brunswick population seems concerned with this collision experience.

3.0 Mitigation Methods

Certain mitigation methods found in the literature are discussed in this section. The effectiveness of each method is

reported according to studies done in other jurisdictions as well as work being carried out in New Brunswick.

3.1 Signing

The most common mitigation method used by highway authorities to reduce the number of collisions with Moose and Deer is the installation of animal warning signs. The Transportation Association of Canada (TAC) recommends specific Deer and Moose crossing signs in the Manual of Uniform Traffic Control Devices (MUTDC) for Canada. The MUTDC prescribes the shape, color, and size of any signs to be used as well as the criteria for their placement. The Deer and Moose crossing signs are described in Section A3.80 of the manual which has been adopted by the New Brunswick Department of Transportation. The installation criteria for these signs are simply stated as where it is known that deer or moose are accustomed to cross the highway.

The effectiveness of warning devices is controlled by driver expectancy and the real probability that a driver will encounter a particular hazard. The overuse of any warning signs can reduce their effectiveness. In fact, the MUTDC states that the overuse of any warning signs will promote disrespect for traffic control devices and should be kept to a minimum. This seems particularly relevant for animal crossing signs since the danger that these

signs are meant to identify is not always present on the highway. The installation of Deer and Moose crossing signs may be rendered ineffective from one year to the next as the animal population moves to another area. The phenomena of such a moving hazard therefore presents particular problems for highway agencies. The New Brunswick Department of Transportation is currently working closely with the Department of the Environment on an installation policy for these warning devices.

3.2 Reflectors

A Deer collision mitigation method currently being used by a number of highway agencies is that of roadside deer reflectors. These reflectors are placed longitudinally along the side of a highway. The manufacturers of this device claim that as vehicles travel along the highway, the lights emitted from the vehicles are reflected off the reflectors and into the adjacent wooded area. The reflectors create a red optical fence on the side of the road. The Deer are frightened by this emission and therefore stay in place until the vehicles have passed by. These reflectors are deemed only effective for Deer and not for Moose. In addition, the nature of this technique means that the reflectors can only be effective in preventing nighttime collisions.

A number of studies have been undertaken to determine the effectiveness of the Deer reflectors. According to the

manufacturer, numerous tests sites have been set up in the United States, Canada, and Austria. The manufacturer also claims that many reports of these test sites prove that the reflectors are successful in preventing a significant number of nighttime Deer collisions. Some of the positive studies found in the literature include Schafer and Penland (1985) and Ingebrigtsen and Ludwig (1986). Both of these studies observed a decline in roadkills and suggested that the reflectors possibly assisted in reducing mortality.

It appears that there is a lack of consensus as to the effectiveness of this mitigation method. Other research reports have concluded that the reflectors are ineffective. Such a study was conducted by the Department of Zoology in Southern Illinois University (Waring, Griffis, Vaughn, 1991). The results of this study showed that deer behavior was unchanged and that roadkills occurring between dusk and dawn were the same after the deer reflectors had been installed. The results of this study are similar to those of Woodward et al. (1973).

In the spring of 1990, the New Brunswick Department of Transportation initiated a project to evaluate the effectiveness of using wildlife reflectors to reduce the number of vehicle - deer collisions in New Brunswick conditions. Two test sites were selected for this monitoring project based on the rate of deer collisions.

The fist site is six kilometer long and is located on Route 10 through a wildlife game refuge. The first three kilometer section was equipped with reflectors while the other three kilometer section was used as a control section.

The other test site is a five kilometer stretch of highway located on Route 1. Similarly to the first site, two kilometers were equipped with reflectors while the remaining three kilometers were used as a control site.

The initial results of the New Brunswick study do not indicate any definite conclusion as to the effectiveness of these reflectors (Jackhart, 1984). An independent review of the New Brunswick results was recently undertaken by a member of the University of New Brunswick Transportation Group. That review also indicated that results are still inconclusive (Hilderbrand and Hodgson, 1995).

Although there is conflicting evidence relating to the effectiveness of deer reflectors, these reflectors are relatively inexpensive to install and maintain. Therefore, the New Brunswick Department of Transportation is continuing to monitor these sites in hope that some positive results will evolve.

3.3 Fencing

There are several types of fencing arrangements which can be used to help solve the problem of vehicle-wildlife collisions. One type is the overhanging style of fencing. A sketch of this fencing type is shown in Figure 1. The purpose of this fencing is two fold. First, it prevents the deer from entering onto the highway right-of-way. The deer approaches the fence and goes underneath. At this point, he will come in contact with the vertical fence. It also allows animals which have gained access to the highway to jump over the fence to get to the field or wooded area.

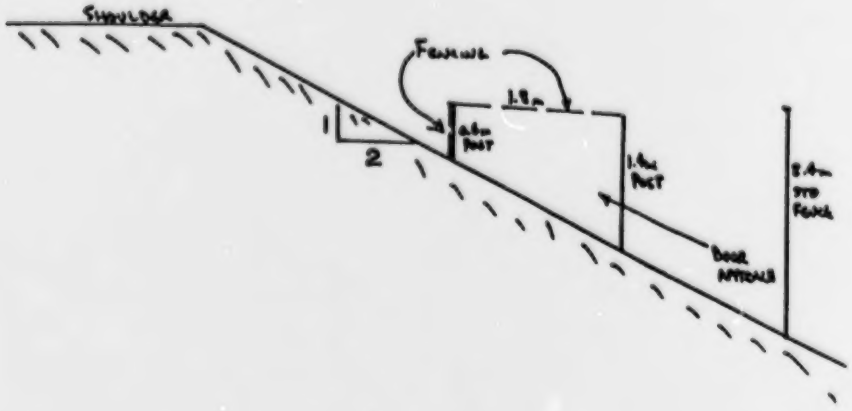

Figure 1 - Overhanging Style of Fencing

One of the main problems with this type of fencing is the high cost. This setup requires a double set of posts and the fencing.

The fencing typically used is a standard woven wire fencing.

The height of this fencing can range from five to ten feet. Studies have shown that a height of eight to ten feet is optimal in preventing wildlife from jumping over onto the highway right-of-way.

It is very important that the fence is well maintained. Any gaps or open areas in the fencing will allow the animal access onto the highway right-of-way.

Another consideration which must be taken into account when dealing with fencing is its location with respect to the wooded area and the highway right-of-way. Studies have shown that the best location for the fencing is approximately 25 yards from the wooded area. This allows a grazing area for the deer on the wooded side of the fence. The animal has no requirement to enter upon the highway right-of-way. Studies have also shown that a low mortality occurs when the fence is located within the wooded area where there is little grazing area on either side of the fence. By placing the fence within the wooded area, maintenance can be a problem due to falling trees on the fence.

The length of the fencing is also very important. A study done by the State of Colorado, Department of Natural Resources, estimates that males and females will move along a fence for

approximately 0.578 km and 0.709 km respectively. The length of fence must be a minimum of this maximum distance on either side of where the deer are concentrated. The length of fence may also be dependent on the terrain. If the animal comes to an area where the terrain prevents him from entering, the fence can be tied into this area.

It is very expensive to provide a 100% deer proof fence. Estimates received from British Columbia Ministry of Transportation and Highways quote a figure of $55,000 to $65,000 per km for both sides of the highway. Cost to maintain the fencing must also be taken into consideration.

In association with the fencing, one-way gates are required. These are V-shaped gates which allow animals which have wandered onto the highway right-of-way access back into the field or wooded area. It is recommended that one-way gates be located at least 30 meters from an underpass.

3.4 Underpasses

The use of underpasses is usually associated with fencing. Fencing is required to channel the wildlife to the structure. Studies have shown that the use of underpasses without fencing is generally low.

One important factor to consider when designing an underpass is the openness ratio. The openness ratio of a structure is calculated as follows:

$$\frac{\text{open end surface area of structure}}{\text{length}}$$

The appearance of the structure is the primary stimulus of a given underpass to approaching deer. A higher openness ration corresponds to the underpass appearing less as a tunnel. The animal must be able to see through the underpass in order to feel secure in using it.

Deer behavior has been observed at various underpasses. Deer were reluctant to use the structures which were more open (higher openness ratio).

It also appears that deer are less reluctant to use an underpass which has a gravel bottom rather than concrete. Often bait, such as hay or apple pulp is used to attract the animal to the underpass.

3.5 Landscaping

Animals often feed from the species of plant which is found on the highway right-of-way. In New Brunswick, mulching and hydroseeding is done to plant the right-of-way. These mixtures

contain a portion of straw and hay. By planting a species which is not attractive to wildlife, animals will be discouraged from entering the highway right-of-way in search of food.

3.6 Highway Lighting

Many vehicle-wildlife collisions occur between sunset and sunrise. Some studies have suggested that by providing lighting during this period, wildlife would become more visible to the motorist and therefore prevent some collisions. Other studies have shown that the number of wildlife crossing the highway increases when highway lighting is provided. There is no firm conclusion on whether highway lighting actually helps in the reduction of vehicle-wildlife collisions.

3.7 Bridge Extensions

Wildlife often travel along a natural watercourse. When a highway is constructed so as it intersects with a watercourse, this travel path may be interrupted. This problem may be solved by extending the bridge structure as shown in Figure 2. This allows the animal to continue his travel as before the highway construction.

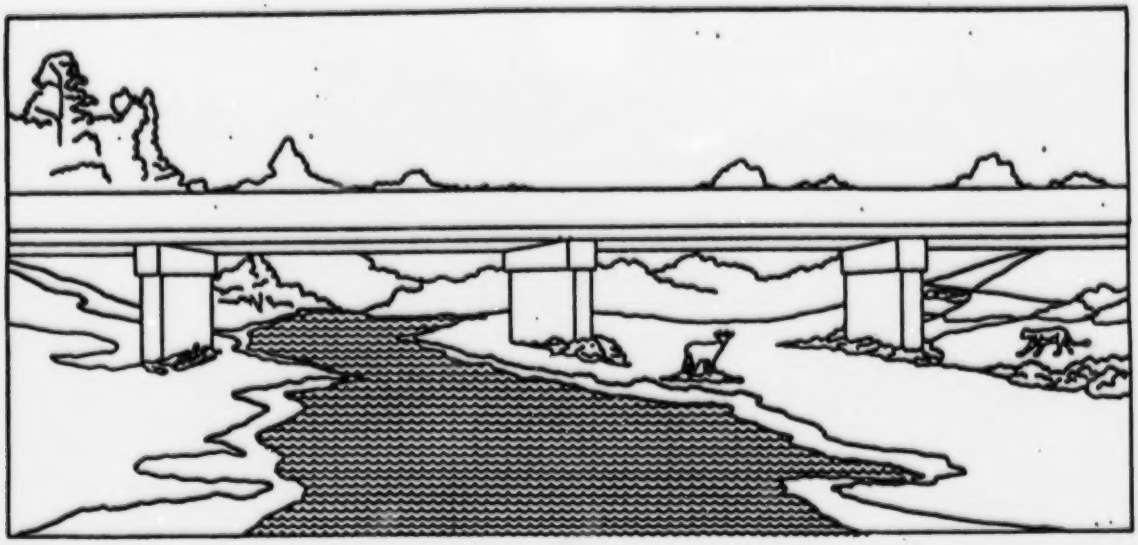

Figure 2 - Sketch of Bridge Extension

3.8 Road Salt

As part of their diet, white-tailed deer require a clow level of salt. Part of this salt quota can be obtained by consuming aquatic plants. Studies have shown that plants located close to the highway have a higher concentration on Na due to the salt used in de-icing the highways. Deer could graze on these plants located close to the highway in order to obtain the Na requirement. A certain amount of salt is required for winter maintenance, but it is suggested that the salt quantity be decreased and increase the quantity of other winter maintenance materials such as sand.

3.9 Public Education

Several jurisdiction in the United States have turned to public education in order to help with the problem of vehicle-wildlife collisions. The purpose of this education program is to make the general public more aware of the problem that exists with respect to vehicle-wildlife collisions. By making the public more aware, the motorists may be more alert when on the highway.

3.10 Other Jurisdictions

In the fall of 1994, the New Brunswick Department of Natural Resources and Energy (NBDNRE) contacted several jurisdictions in the United States and Canada requesting information on the subject of deer/wildlife crossing corridors and associated infrastructure. Information was received from the majority of the States and some areas in Canada. A summary of the information received from each jurisdiction in located in Appendix A.

Table 1 indicates the number of locations using each mitigation method and the result of each.

As this table illustrates, it is felt there is no one method that is absolutely effective.

The three main mitigation methods currently being is fencing,

signing, and wildlife relectors.

From the information recieved, fencing appears to be the most effective method in reducing vehicle-wildlife collisions. Areas in which fencing did not seem to be effective was due to the height of fence (height being only 5 to 6 feet) or that the fence was not well maintained. It also seems apparent that fencing is required with the use of underpasses.

Method	No Comment	Effective	Not Effective	Not Conclusive	Under Consider ation
Fencing	3	4	5	1	0
Signing	14	1	2	0	0
Reflector	2	1	3	4	2
Underpass	1	1	0	2	1
Bridge Extension	1	0	0	0	0
Noise Wall	1	0	0	0	0
Landscape	1	1	0	0	0
Bridge	0	1	0	0	0
Clearing	1	0	0	0	0
Public Education	1	0	0	0	0
Overpass	1	0	0	0	0

Table 1 -Summary of Mitigation Methods

Signing is used in most areas but the majority of jurisdictions did not state whetheher they felt this was an effective mitigation method.

The effectiveness of reflectors is not conclusive. In some areas relectors were effective while in others they were not. No apparent reason is available for this discrepinsy.

4.0 Mitigation Methods Used in New Brunswick

Only within the past few years has the problem of vehicle-wildlife collisions become a major issue with the New Brunswick Department of Transportation(NBDOT). Recently, mitigation measures are being used in highway work being done in areas where there is a large deer concentration.

4.1 Norton to Sussex

In 1994, a four lane highway was designed between Sussex and Five Points (Route 111 to Picadilly Road). This new 11.0 km highway passes through as area where there is a large deer concentration. Through discussions held with between NBDOT and NBDNRE, it was determined that some sort of mitigation method would be required in this area.

The mitigation method used for this project was four

underpasses of the type shown in Figure 3. These underpasses are 7400 x 3790 SPCSP arch pipes. They are located in two locations (one underpass for each set of lanes for each location) approximately 2.5 kilometers apart. The length of these underpasses range from 40.5 meters to 44.0 meters which corresponds to an openness ratio of 1.06 to 0.98 respectively. It has been determined that the minimum openness ratio which would be used in New Brunswick would be 0.85.

In association with these underpasses, fencing will be used. It has not been determined at this time whether fencing will be used for the entire length of the job or for a certain distance on either side of the underpasses.

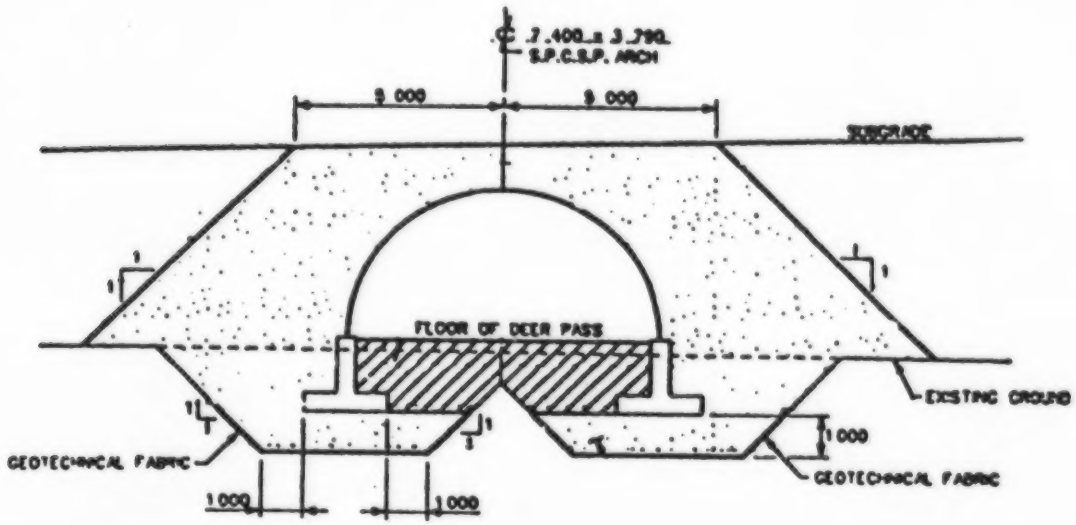

Figure 3 - Deer Underpass

4.2 Lepreau Bypass

A four lane divided highway has been proposed in the Lepreau area. This highway passes through two deer wintering areas. During the Planning stage, it was decided that deer crossing would be provided in this area under the twin structures which pass over the Lepreau River. The decision to locate the deer crossing in this area was determined after several discussions between NBDOT and NBDNRE.

5.0 Cost Benefit Analysis

Cost figures were available for installing deer reflectors and for the combination of fencing with underpasses. The financial benefits associated with animal collisions are discussed and then compared to the costs of using these two mitigation methods.

5.1 Benefits of Accident Reduction

To assess the financial feasibility of any mitigation method, it was necessary to estimate the financial benefits of reducing the number of collisions. The property damage estimates contained in the deer and moose accidents reported by police officers were averaged for the years 1992 to 1994 inclusively. It was determined that the average property costs associated with a vehicle colliding

with a deer is approximately $2200 dollars while the property damages associated with a moose accident are in the area of $3800 dollars.

A recent study reported that Transport Canada estimates accident costs in the vicinity of $390 000 dollars for a fatal accident, $12 000 dollars for an injury accident, and 3 100 dollars for a property damage accident (Landry, 1993). These costs are deemed to incorporate losses of income, property damage and health care.

The benefits of preventing deer and moose accidents can be estimated using these cost figures and the breakdown of accident severity. Since five percent of deer accidents result in injury and ninety-five percent result in property damage, the benefit of preventing (N) deer accidents can be calculated as: Benefit = N (0.05 x 12 000 + 0.95 x 3 100) or
(N x $3545).

Similarly, since one percent of moose accidents result in fatalities, twenty -five percent result in injuries, and the remaining seventy-four percent are property damage accidents, the benefit of avoiding (N) moose accidents can be calculated as: Benefit = N (0.01 x 390000 + 0.25 x 12 000 + 0.74 x 3 100) or (N x $9194).

5.2 Benefit vs. Cost of Reflectors

Based on the undergoing deer reflector study in New Brunswick, the installation costs for reflectors is in the vicinity of $ 8 100 dollars per kilometer. The maintenance costs associated with these reflectors are approximately $ 500 dollars per kilometer per year (Jackhart, 1994). Assuming a fifteen year life span, a ten kilometer reflector system would cost approximately ($8100 x 10km + $500 x 10km x 15 years) = $156 000 or
$ 10 400 dollars per year over its life.

Based on the $3545 dollars saved per deer accident prevented, the deer reflector system needs to prevent approximately 3 accidents per year over a 10 kilometer section to recover the system's cost. However, reflectors are only effective at night, and only 60 percent of deer accidents occur at night. Therefore, the reflector system will only be cost effective in areas experiencing approximately 5 deer accidents per year on a 10 kilometer section.

New Brunswick Department of Transportation maps containing the location of deer and moose accidents for the years 1992 and 1993 were reviewed for the purpose of this paper. It was determined that only 7 highway sections of ten kilometers experienced an average of 5 or more deer accidents per year over the two years. This would indicate that assuming the reflectors are successful in

preventing deer collisions, there are seven sites in New Brunswick where it would be financially feasible to install reflector systems.

5.3 Benefit vs. Cost of Fencing and Underpasses

Information obtained from British Columbia estimates a cost of approximately $ 60 000 per kilometer for the installation of deer fencing. The literature reviewed indicates that maintenance of fencing is very expensive, however, no costs were mentioned. As a conservative estimate, the maintenance of fencing was assume to be $1000 dollars per kilometer per year.

The New Brunswick Department of Transportation recently constructed a new stretch of highway from Norton to Sussex which contains four deer underpasses in a section of approximately ten kilometers. The construction costs associated with these underpasses were in the vicinity of $ 200 000 dollars per underpass.

Similar to deer reflectors, the cost of providing fencing and underpasses was estimated for a ten kilometer section assuming a life span for the fencing of fifteen years. Therefore, the yearly cost of such a system can be calculated using: ($200 000 x 4 + $60 000 x 10 km + $1000 x 10 km x 15 years) = $1 550 000 dollars or $103 000 per year over 15 years.

The cost effectiveness of this mitigation technique can be estimated using the estimated cost savings of $ 3545 dollars per deer accidents and $ 9194 dollars per moose accident prevented. To recover the installation cost, the fencing and underpasses would have to prevent 103000/ 3545 = 29 deer accidents per year over the ten kilometer length. Similarly, a total of 103000/9194 = 11 moose accidents need to be prevented every year over the ten kilometer to financially justify the system.

From the provincial maps containing the location of deer and moose accidents, it was evident that such an expensive system is not financially feasible. The highest concentration of deer accident over a ten kilometer section of highway was 8 accidents per year over the two years studied. Similarly, the highest concentration of moose accidents over a ten kilometer section was 6 accidents per year over the two year period.

6.0 Conclusion

There seems to be no scientific evidence relative to the effectiveness of some of the design considerations discussed in this paper. However, it appears that appropriate landscaping, bridge extension designs, highway lighting, and appropriate use of salt all hold potential for the reduction of vehicle collisions with deer and moose.

As for mitigation methods, highway warning signs are believed to produce only minimal results in preventing ungulate collisions.

The effectiveness of roadside deer reflectors is still inconclusive in New Brunswick. However, if it can be shown that these systems do in fact reduce the number of nighttime deer collisions, then reflectors can provide a financially feasible mitigation method where concentrations of deer collisions are found.

The installation of fencing in conjunction with the construction of underpasses are very effective in mitigating deer and moose accidents. However, this type of system is a very expensive endeavor. This paper has shown that if financial recovery is a determinant for this kind of system, the concentration of deer or moose accidents in New Brunswick does not warrant their installation.

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New Mexico State Highway and Transportation Department
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Maryland Department of Transportation
West Virginia Department of Transportation
Connecticut Department of Transportation
New Jersey Department of Transportation
North Carolina Department of Transportation
British Columbia Ministry of Transportation and Highways
Colorado Department of Transportation
Arkansas State Highway Commission
Alaska Department of Transportation and Public Facilities
Maine Department of Transportation
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Florida Department of Transportation
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Iowa Department of Transportation
Rhode Island Department of Transportation
Michigan Department of Transportation

APPENDIX A

SUMMARY OF CORRESPONDENCE

State of Utah - DOT

- evaluated various techniques - deer-proof fencing with underpasses or overpasses, deer crossing signs, intercept feeding, Swareflex warning reflectors, ultrasonic wildlife warning whistles
- deer-proofing with overpasses or underpasses and one-way gates are successful when installed in appropriate locations
- observations have shown that the effectiveness of deer warning signs is minimal due to driver acclimation
- an ongoing study underway to understand mule deer-highway relationships and evaluate an experimental big game-highway crossing structure. Have incorporated one-way gates into the deer-proof fence associated with the experimental crosswalks. Wyoming Game and Fish Department have utilized "earthen berms" in lieu of one-way gates.

State of Michigan - DOT

- main source of preventative control is through advance signing, indicating possible high volume deer crossing areas

State of Rhode Island - DOT

- has used wildlife tunneling. The chosen area was a natural travel corridor (a valley with a brook and its associated wetlands) by wildlife species. Size of four tunnels determined by size required for the animals to be comfortable using the tunnels and where the highway embankment was tall enough to facilitate culvert installation. All four tunnels were 30 feet wide at the base, three were 13'8" high, one was 11'4" high and the tunnels were spaced 200' apart

Iowa - DOT

- generally have not attempted top fence locations where deer are inclined to cross the highway
- considerable number of deer crossing warning signs have been placed at locations where there is a large number of deer crossing the highway or where there has been a number of accidents

Commonwealth of Massachusetts - Transportation and Construction

- use standard deer crossing and moose crossing signs
- current design policy along limited access highways in massachusetts requires six-foot chain link fencing along the highway right-of-way boundary. Deer can easily jump over a fence of this height. Highway department looking at alternatives in

areas of high deer concentrations
- has looked into a Swedish-made chemical called Wolfin which is derived from wolf urine and provokes a fear response in deer and moose
- flapping flags, brightly colored materials, and the like appear to have little or no effect as deterrents to deer
- have recently completed an underpass for deer and other wildlife. Structure is a corrugated steel culvert with a diameter of 18 feet. Gravel is spread along the bottom of the structure to provide adequate footing, and a small stream passes through it. No information on whether structure is being used

New York Department of Transportation

- a large deer population exists
- little success with controls such as fences and gates
- rely on highway warning signs, located by the local highway managers as main safety control
- no research done on this subject

New Mexico State Highway and Transportation Department

- Department has some concern with the deer/wildlife crossing corridors
- May 1995, completed the final inspection of a 3 year evaluation for the Swareflex Wildlife Delineators Product
- result of evaluation do not show any conclusive findings that would warrant future use of product
- one solution the Department is pursuing is game fence to funnel the wildlife to safe crossing locations

Summary of Delineator Program

spacing of del. - approximately 66 feet longitudinally and 12 feet from shoulder. Reflector lenses aligned to suit conditions of terrain along with the manufacturer's recommendations. Damage to the reflectors occurred due to snow plow and mower operations. Permanent damage - twisted posts therefore no longer serving its purpose, minor damage - turnouts and possible vehicle knockdowns. Also , during peak snowfalls, reflector lenses were dirty with road grit due to water/grit splashing of passing vehicles.

year	wildlife/vehicle accidents
1987	0
1988	0
1989	19
1990	11
1991	35
1992	15
1993	n/a
1994	n/a

reflectors installed between 1990 and 1991.

Variations in the wildlife kill may not reflect effectiveness of reflectors but may imply a change in the migratory patterns due to climatic seasonal. No conclusive findings from study.

North Dakota Department of Transportation

- has been installing silver "Deer Mirrors" (Van Dee Ree Dutch mirrors) at selected locations where a night time accident problem has been identified (attached drawing illustrates devise and spacing)
- since prairie state, there are very few specific wildlife travel corridors, elected not to install "Deer Crossing" signs
- red "Deer Mirror" (Swanflex System) also available. Have not used this type of mirror

Maryland Department of Transportation

- currently evaluating the effectiveness of the Swanflex Wildlife Reflector

West Virginia Department of Transportation

- recently installed eight-foot-high fencing on several miles of road. Initial reports indicate the higher fencing has reduced the number of deer killed by motor vehicles

State of Connecticut

- no studies performed regarding deer or other wildlife crossings
- a problem does exist with deer/vehicle collisions
- State currently erects signs where there is a frequency of deer crossing state-maintained highways
- have considered Swareflex reflectors, but not convinced of their efficiency
- all freeways are fenced, but this has not had any apparent effect on deer crossing

State of New Jersey

- many methods being tested by NJDOT to prevent animals on state highways
    1. Fencing - 8 to 10 foot high fence used, but increasing amounts of residential/commercial developments precludes the placement of such fencing
    2. Dry Culverts - in constructing new bridges and roadways,

where fill is required, NJDOT installing dry culverts (unattached to any drainage or stormsewer systems) which allows small animals to cross under highway
3. Animal Overpasses - land bridges constructed over highway
4. Expanded Bridge Widths - many new bridges being lengthened with larger stream opening, thereby allowing for the retention of dry land under the bridge for animal usage
5. Noise Walls - built along highways to reduce noise, but also helps to reduce the amount of animals which can access the highway
6. Reflective Mirrors - limited success, maintenance and upkeep a problem
7. Landscaping - vegetative plant and grass species conducive to wildlife usage as a food source are being substituted for more palatable species along the ROW corridors. This discourages animals from wandering along the roadways in search of food

State of North Carolina

- Swareflex Wildlife Reflectors used on a experimental basis. No formal documentation on effectiveness of reflectors, but Department believes the number of deer/vehicle collisions has decreased after installation. This is based on documentation related to the number of dead deer removed from the highway. Due to the terrain, effective reflector spacing may be as close as 15 feet ($10,000/mile). Reflectors are easily stolen and vandalized. They also hamper roadside maintenance (especially grass mowing).
- in a few areas, the size of reinforced concrete box culverts was increased to accommodate the movement of animals. The Department has also constructed a 3 span bridge for this purpose. Animals effectively using bridge crossing but no information on effectiveness of oversized culverts.
- does not believe the Department can feasibly provide a fence high enough to prevent deer from clearing it
- use standard W11-3 (30" x 30") deer crossing sign

Province of British Columbia

- serious problem in B.C. with over 4600 such accidents per year in 1993
- presently use wildlife fencing - one of the most effective methods of reducing deer-vehicle accidents. Wildlife fencing usually refers to fencing and other controls such as wildlife over/underpasses and one-way gates. Fence is 2.45 m high. (Specifications given for wildlife fencing)
- wildlife reflectors and mirrors are installed along the sides of highways. Wide range of external factors which may affect study results: 1. migratory habits of wildlife - animals that migrate long distances, depending on their migratory routes can be much

more likely to be involved in wildlife vehicle accidents, 2. Weather - extreme weather conditions can act as an overriding incentive for animals to seek out more favorable areas, regardless of what "deterrents" may be in their way, 3. Biological Needs - during rutting season the biological pull on males to follow females can be a predominant factor as to whether or not males would be deterred from entering a roadway, 4. Predators - the immediate necessity to avoid predators mat overshadow caution in terms of crossing over an artificial barrier, such as an optical fence.

State of Colorado

- uses a standard woven wire deer fencing for known areas of migratory deer pattern locations. Fencing has a one-way gate opening built to allow a deer who has strayed onto the highway, access back into the field area
- have used underground tunnel with fencing surrounding the sides. After three nights, the deer started movement under the tunnel to access water on the other side
- also provides signing. When more serious problems exist, a flashing light is added to the top of the deer crossing sign

Arkansas State Highway Commission

- uses warning signs at sites that have multiple deer/vehicle accidents occurring
- have not used fencing
- experimented with specialized deer reflectors at two sites but consider effectiveness to be marginal at this time

State of Alaska

- approximately 500 collisions per year. This number can double under heavy snowfall. It also may be 15% higher due to unreported accidents
- have done a study on moose - vehicle accidents on Alaska's rural highways. Potential solutions were as follows:
1. Do Nothing Alternative - in areas where concentrations are average or below
2. Route Alignment - during planning, avoid crossing moose habitat. May be costly.
3. Public Awareness Program - tried in Newfoundland and Sweden - pamphlets, brochures
- bumper stickers, school discussions, highway signs - after one year approximately 18% reduction, after two years, unsure, presence of signs now familiar to travelling public
4. Warning Signs
5. Speed Limit Reductions - felt this would have little effect. Studies show drivers select speed based on conditions rather than

speed limit

6. Planting to Inhibit Roadside Browse - without maintenance, roadside becomes overgrown with willow, birch trees, aspen. alder, and cottonwoods. Many areas become forage for moose in summers and severe winters. A grass mixture was planted along several highway segments which include a 30% mixture of Arctared Fescue, a grass which will grow reedy and "spiny" by its second year. The grass was planted in the fall and it stayed lush and green long after wild brush had dropped it leaves. It was planned to inhibit growth of browse and control erosion. The most critical effect of these projects may not have been the grass mixture but the time of planting and the amount of fertilizing. In 1991, nearby trees were delimbed and Arctared Fescue planted. The results appear successful so far, but no controlled study has been undertaken. More study required to determine proper time and mixture of roadside seeding required to inhibit browse growth.

7. Clearing - one of the most common solutions to moose /vehicle collisions. Clearing can be performed by a variety of methods - hydoaxing with heavy equipment, hand clearing, steam clearing, spray inhibitors, grubbing. With regards to moose, time of year clearing is done is very important. Best to start in early summer as plants invest nutrients in above ground growth, and less in its root system

8. Reduce Population Densities - For moose, this is done in Newfoundland. Control method would be in the form of a April/May spring hunt. With respect to deer, other states suggested a birth control through darting and chemical injection as a potential control method.

9. Alternate Forage Areas - acreage off of the highway can be cleared in order to develop browse for moose. This is expected to attract moose away from the highway. Area must be carefully located - if location too close to highway, it may dram moose near the highway. Also not a good idea to have cleared area on both sides of the highway.

10. Swareflex Deer reflectors - have been successful in mitigating deer collisions in some Washington State studies. Test results on deer reflectors for moose are undocumented and appear to have little control. An early 1970's test on in Alaska appeared to have little effect on moose

11. Wildlife Mirrors - Van de Ree mirrors, reflect light at right angles to the highway, just as Swareflex reflectors do. Appear to have been successful in one study in Maine and another study in the Netherlands which have noted a 100% reduction in accidents. Sweden application for moose was unsuccessful and discontinued their use for other methods.

12 Delinator Backdrop - The backdrop is composed of a frequent

series of sign panels which reflect light back to the driver. Any animals in front of these panels block the reflection, interrupting the signing pattern, and becomes discernible by the driver. Purpose is to increase the drivers ability to see a moose.

13. Ultrasonic Sound Devices - a pair of horns can be mounted on vehicles which makes a high frequency sound as wind blows through it. This was tried on moose in Sweden but considered unsuccessful.

14. Moose Fencing and Moose Underpasses - effective solution for controlled access highways but more difficult to install with the presence of driveways.

15. Continuous Illumination - increase visibility for motorists. Study done in Alaska - eight miles of continuous lighting on a controlled access divided highway. There was enough traffic in winter months to warrant lighting regardless of moose-vehicle collisions. Two reviews of the project showed a 90% reduction in collisions in lighted areas.

16. Future Technological Advances - ultraviolet headlights for cars - still five years away from potential application). The headlight is designed to illuminate the moose, reflecting them in a light blue color to the driver. It uses ultraviolet light capable or reaching four times the distance of normal headlights. This light is invisible to the driver. There are still questions about possible health effects of ultraviolet light on the eyesight of other drivers. Another future solution - infrared night goggles could lead to advanced windshield designs for private automobiles.
17. Other "Lesser" Options -

State of Maine - DOT

- looked at deer mirror system in late 1970's. No evidence to support claim that mirrors were effective
- Swareflex Wildlife Reflector System being considered for a test installation in Northern Maine
- do install deer and moose crossing area warning signs when requested by Maine Department of Inland Fisheries and Wildlife

State of Tennessee - DOT

- no research performed
- utilize deer crossing signs where deer are known to cross in large numbers

Commonwealth of Kentucky - Transportation Cabinet

- list of references

State of Wisconsin - DOT

- fencing appears to have no effect on deer travel. Have fenced many locations on freeway system where deer hits remain a problem.
- do install a lot of warning signs
- removing tree groves and brush on highway ROW makes it less attractive for deer to cross at that point, and it also makes them more visible. Deer are attracted to water, clearing near water may be effective
- deer reflectors installed on short segments of state highways. Results are inconsistent. May be effective if reflectors are properly maintained. Have learned that Minnesota DOT is discontinuing usage of the reflectors

Commonwealth of Virginia - DOT

- no formal set of policies regarding deer/wildlife crossing control
- use "deer warning" signs where deer are known to cross frequently or where accident records reveal a high incidence of deer/vehicle collisions
- utilize fencing along ROW of limited access highways as a general deterrent to encroachment on the highways. Height of only 5 or 6 feet. This height does not provide absolute protection against deer crossing

Oklahoma Turnpike Authority

- sign established deer crossings
- have four known deer crossings on entire turnpike system

Government of the District of Columbia - Dept of Public Works

- District of Columbia located in an urban metropolitan area, therefore the Department of Public Works does not have an involvement concerning deer and wildlife crossing corridors

State of Oregon - DOT

- uses two kinds of signs - one pictorial and the other written - to alert motorists of deer and elk crossing corridors
- have fenced ROW for a number of years but has not prevented wildlife from crossing at any spot along highways - they still manage to jump over or get through the fencing. Type II fencing generally used

State of Indiana - DOT

- gave list of documents, reports

State of California - DOT

- summary of report indicates driver warning signs and ROW vegetation removal effective in reducing the highway deer kill but fencing and undercrossings need further evaluation (84 inch diameter metal pipe used)
- Swareflex Wildlife Reflectors warning system used. After three seasons, there is no statistical difference in mean of deer killed

State of Vermont - Agency of Transportation

- does install deer crossing signs along highway, there has been no formal study to prove effectiveness
- Swareflex Wildlife Warning Reflectors research indicates Swareflex reflectors are ineffective

South Carolina - DOT

- geographic characteristics of South Carolina is such that deer do not utilize wintering areas as do their northern counterparts, therefore there are no defined wildlife corridors to be concerned with
- - if 3 or more deer/vehicle collisions occur within a 1 mile section during any given year, installing "deer crossing" warning signs are considered
- fencing utilized mainly on interstate routes, but design does not deter deer from entering or crossing these facilities. To install fencing that would prevent encroachment by deer would be quite expensive and could not be justified from a cost/benefit standpoint
- currently testing a three flange reflector that spins with the slightest breeze, thus reflecting oncoming vehicle headlights into the wooded area adjacent to the roadway in a strobe effect. Study not completed until August 1995. One problem is that the devices are frequently vandalized.

State of Kansas - DOT

- has installed "deer reflectors" - Swareflex - at two locations. One location seems to be effective and the other inconclusive
- installs W11-3 "deer crossing" signs at locations where there is a high number of deer hits

State of Wyoming - DOT

- has standards for deer fence, one way gates, and ramps

State of Louisiana - Dot and Development

- have a large deer population
- have not experienced a problem with public safety associated with wildlife accidents
- do install "deer crossing" signs in some areas to warn motorists

Nebraska - Department of Roads

- deer accidents show a trend of steady growth

State of Minnesota - DOT

- have used three methods to minimize vehicle/deer accidents
1. signing - studies have not been done, but it is felt that signing is minimally effective in reducing vehicle/deer collisions
2. deer fencing - two locations where fencing has been installed. Both installations have been effective. Fencing was 2.4 m in height.
3. deer warning reflectors - have installed Swareflex reflectors along many sections of highways. Success has been varied. Maintenance of reflectors extremely difficult and in some areas considered a low priority. Exercising constraint in establishing reflectors at additional locations
- deer underpasses have not been tried but there is an interest in doing so

South Dakota - DOT

- deer/vehicle accidents are a problem involving 30%of all reported rural accidents
- have not employed the use of fencing to prohibit or redirect deer or elk to cross at given locations
- do use deer warning symbols at locations where known frequent crossings occur
- have installed Swareflex Wildlife Warning Reflector Systems on some select segments of highway system. Results at three locations:
Location 1 - installed May 1986 - number of deer killed went down from 17 in 1984- 1985, 2 in 1987, and 2 in 1988
Location 2 - installed December 1986 - number of deer killed went

from 9 in 1984, 3 in 1987, and 2 in 1988
Location 3 - several deer killed in area before installation, one deer hit since installation of deer reflectors (two have been hit just outside the reflectored area). Cost (1986) - $3360.00 for 640 reflectors - three different types

Commonwealth of Pennsylvania - DOT

- study available "Wildlife Passage Study"
- list of abstracts and contact information
- summary of questionnaire on Swareflex Reflectors
- received report concerning effect of highway opening on Wildlife movement patterns. The main conclusion from this report was that white-tail deer would not use large culverts provided since the were long and light was not visible at the end of the tunnel

Texas - DOT

- title of document "Effectiveness of Wildlife Crossings in Reducing Animal/Auto Collisions On Interstate 75, Big Cypress Swamp, Florida

Florida - DOT

- have used informational signing and speed limit reduction with limited success
- have also used fencing in association with crossing structures and feel it is necessary to guide the animal to the crossing. Trying to treat areas as large as a mile wide with a single structure. Using a 10 foot high fence with three strands of barbed wire which is proving effective.
- Report on the Animal Crossing Study by the Florida Department of Transportation - objective was to develop a cost-effective wildlife crossing that has a high probability of use by larger animals. Range of heights were 6 to 8 feet, Range of widths were 10 feet to 50 feet. The design using an 8' by 24' precast segmental box culvert with 2.5% roadway profile grades was identified as the most cost effective design which had a high probability of use by larger animals. Cost - approximately $550,000 when retrofitting a 2 lane rural highway or $250,000 when part of a new construction project. During study, it was reported that wildlife crossing were used successfully for several larger animals - deer, elk, etc. but quite costly. A single 8' by 100' bridge crossing would cost approximately 1.1 million dollars to engineer and construct. Materials studied - concrete (standard box culverts, pre-cast segmental box culverts, reinforced earthwall design with a concrete slab), metal (aluminum and steel box culverts and arch pipes), wood (problems with deterioration and maintenance make this material

unsuitable for long term use). Various heights and widths were tested.

Ohio - DOT

- DOT, Public Safety and Natural Resources are cautioning motorists this season (1995) through an extensive public relations campaign to be aware of deer while travelling Ohio's highways, especially at dawn and dusk when deer are most active and traffic is heaviest
- also use standard deer crossing sign

Transport Canada

- have not carried out any research on the topic
- list of contact people